CHINA ~ SHANGHAI

ABSTRACT

The Shanghai Energy Option and Health Impact Assessment, funded by USEPA, was carried out by Shanghai Academy of Environmental Academy (SAES) and Shanghai Medical University (SMU) from early 1999 to August 2000. Current energy supply and consumption, SO_2, NOx and CO_2 emissions, air pollution levels, and health effects were analyzed. Bottom up energy demand by sector from 2000 to 2020 were projected, based on economic growth and energy demand elasticities. The Markal model (a professional energy optimization model, and energy technology system analysis programme) was used in this project for energy technology selection, and local air pollution emission and CO_2 emission analysis upon the requirements of energy and environment policies which are listed in China's Agenda 21 – Shanghai's Plan of Action (Shanghai, June 1999). Shanghai Environmental GIS linked with air pollution dispersion models were adopted in air pollution exposure level forecasting. The results show that energy and environment policies will play important roles in air pollutant emission reductions, local air quality improvement, and policies will also have co-benefits for health and CO_2 emission reductions in Shanghai, China.

INTRODUCTION

Goals and Rational

The project was undertaken by Shanghai Academy of Environmental Academy (SAES) and Shanghai Medical University (SMU), with the support from US Environmental Protection Agency (USEPA), China Council for International Cooperation on Environment and Development (CCICED), World Resources Institute (WRI), and Shanghai Environmental Protection Bureau (SEPB). The objectives of Shanghai Energy Option and Health Benefit study were to understand:

- The current status of energy consumption, and pollutant and CO_2 emissions in Shanghai;
- Future energy demand and its emissions under energy and environmental policies for 2000-2020;
- Health benefits due to energy and environment policies.

Relationship with Other Local Studies

Several local air pollution control studies have been carried out in Shanghai in recent years. These studies have analyzed local air pollution control master plans, SO_2 and TSP emission control, and most recently NOx emission control studies related to mobile sources. Most of these studies have focused on the energy sector and specifically on coal use. Local air pollution studies have built a solid base of useful analysis tools for this project, for instance the Shanghai Environmental GIS (SEGIS) and an air pollution dispersion model linked with SEGIS that provides gridded pollution exposure level forecasting on the scale of 1x1 km^2.

Project Team

The project had two components. The first part was the subproject on energy option and emission scenario analysis carried out by SAES. The second part involved health analysis undertaken by SMU. The work of the above two groups was linked by the results from modeling work on energy option and pollution exposure level produced by SAES.

The project was managed by Professor Lu Shuyu, Director of SAES. The members of the local team are listed bellow:

Energy and Emission Team

Team Leader:	Dr. Chen Changhong, Deputy Chief Engineer, Professor of SAES
Team Members:	Mr. Zhang Junliang, Engineer, SAES
	Miss Fu Qingyan, Engineer, SAES
	Miss Shen Hong, Engineer, SAES

Health Study Team

Team Leader:	Dr. Chen Bingheng, Professor of SMU
Team Members:	Mr. Zhu Huigang, Professor of SMU
	Dr. Hong Chuanjie, Professor of SMU
	Mr. Song Weimin, Professor of SMU

METHODOLOGY

Methodology and Approach for Energy and Emission Study

The Markal model (MARket Allocation model), an energy optimization model which is an energy technology system analysis programme, was used in the energy option and emission analysis. Shanghai Markal contains 29 energy demand vectors, 23 energy carriers, 22-Materials, 23 industrial processes, 19 residential technologies, 14-transportation technologies, 37-process technologies.

Three energy option and environment policy scenarios were defined in the study:

(1) Business As Usual (BAU) as a baseline with economic growth and non-options;

(2) Energy Option (EP) including a total limit on coal use, total capacity limit for coal burning power plants at 12 GW, energy substitution with imported natural gas from the East China Sea and the western part of China, electricity import from the Qinshan Nuclear Power Station and the Three Gorges project, and final energy use shifting from coal to natural gas;

(3) Environmental policy (EP+ENV) in addition to the energy options for scenario (2), environmental assumptions included SO_2 and NOx emission control targets in year 2000-2020. Sub-targets of NOx emission control for mobile and non-mobile sources were defined in the study, because of the different exposure impacts of the two sources.

In order to understand future pollution exposure level, SEGIS with all emission source locations, and an air dispersion model with point, volume, area and linear source model, were used in ground level air pollution exposure level forecasting. The input data was generated from Markal energy optimization results.

Key Scoping Decisions that Defined the Project

In order to understand future pollution exposure level, SEGIS with all emission source locations, and an air dispersion model with point, volume, area and linear source model, were used in ground level air pollution exposure level forecasting. The input data was generated from Markal energy optimization results.

The air pollutants SO_2, NOx and PM_{10} were identified as significant for local health effects analysis in Shanghai, China. However, with the limitation of PM_{10} emission factors for different energy technology and fuel burning facilities, analysis of PM_{10} emission control options and scenarios were set aside for future study efforts and SO_2 and NOx were selected as local emission control indicators in this study.

Assumptions of Energy and Emission Projection

Some assumption were made to project future final energy demand projections, including assumptions concerning city population, economic growth rate, and GDP contribution by sectors. The future population and economic growth rates from 2000 to 2020 are listed in table 1.

Table 1: Shanghai City Population and GDP growth

Year period	City Population (million)	GDP Growth Rate of City Wide (%)	GDP growth rate by Industries, %		
			Primary Ind.	Secondary Ind.	Tertiary Ind.
2000-2005	1.31-1.50	9.0-11.0	2-1.5	48-43.5	50-55
2006-2010	1.50-1.53	7.5-9.5	1.5-1	43.5-39	55-60
2011-2020	1.53-1.59	6.5-8.5	≈1	39-	60+

Data listed in table 2 shows the baseline of final sector energy demand in the future, which was projected on the basis of the assumption in table 1 and the sectoral energy elasticity.

Table 2: The Baseline of Final Energy Demand, 2005-2020 Unit: PJ

Year	Agriculture	Industry	Commercial	On Road Trans.	Bunkers	Residential	Total
1995	15	729	60	63	52	37	956
2005	26-29	782-875	124-160	118-135	118	94	1261-1411
2010	29-37	831-1019	156-235	168-118	152	107	1422-1760
2015	33-45	890-1205	206-352	213-211	181	132	1654-2209
2020	36-55	963-1393	283-541	254-294	219	152	1907-2744

Table 3 shows that if there were no further energy and environmental policy changes beyond 1995, local air pollutant and CO_2 emission would be doubled in the next 20 years.

Table 3 Air Pollutant and CO_2 Emissions under BAU Scenario, 2005-2020

Environment Indicator	Sectors	1995	2000	2005	2010	2015	2020
SO_2 (kt)	Power Generation	281	363	471	553	631	756
	Industry	186	149	156	169	175	171
	On Road Transportation	6	7	18	32	42	52
	Bunkers	13	23	23	27	31	34
	Residential	28	25	21	18	14	11
	Commercial	9	7	13	18	26	41
	Agriculture	2	5	6	8	9	10
	Total	576	578	708	823	927	1075
NOx (kt)	Power Generation	145	169	200	233	274	327
	Industry	110	129	138	143	151	150
	On Road Transportation	80	106	143	192	254	316
	Residential	9	11	8	9	8	7
	Commercial	3	4	7	10	14	21
	Agriculture	0.0	0.0	0.0	1.0	1.0	1.0
	Total	347	419	496	588	702	822
CO_2 (Mt)	Power Generation	36	45	58	68	79	94
	Industry	61	66	68	73	80	86
	On Road Transportation	5	8	8	9	11	13
	Bunkers	3	4	7	10	12	14
	Residential	6	7	6	5	5	4
	Commercial	4	4	8	10	15	23
	Agriculture	1	1	2	2	2	3
	Total	116	136	157	177	204	238

Scenarios Defined

Energy and environment policy assumptions for the alternative scenarios were introduced from the publication, China's Agenda 21 – Shanghai's Plan of Action (Shanghai, June 1999).

- Energy policy (EP): assumptions included the limitation of coal consumption to less than 50 Mt, control of total capacity of coal fired power plants to under 12 GW, import of electricity from the Three Gorges project (TGP) and the Qinshan Nuclear Power Station (QSNPS), and import of natural gas from East China Sea (ECS) and western China.
- Environmental policy scenario (EP+ENV): assumptions were combined with EP scenario, and were established through consideration of total SO_2 and NOx emission control targets.

Table 4 Definition of Energy and Environment Policy Scenarios

Scenario	Policies	Unit	1995	2000	2005	2010	2015	2020
EP (Energy policy scenario)	Limit of Coal use	Mt		50	50	50	50	50
	Coal fired power generation	GW		12	12	12	12	12
	Gas unit	GW						2.1
	Import elec. From QSNPS	GW			0.3	0.65	0.65	0.65
	Import elec. From TGP	GW				3	3	3
	Import gas from ECS	M m^3/d		1.2	1.2	1.2	1.2	1.2
	Import gas from western China	Billion m^3/yr.				3.7	3.7	3.7
	LNG Import	Mt				5-6	5-6	5-6
EP+ENV (Energy + environment policy)	SO_2 emission control target	kt		500	450	420	400	350[1)]
	NOx emission control target for transportation	kt			132			75[1)]
	NOx emission control target (city wide)	kt			430			400[1)]

1): the emission control target for SO_2 and NOx in this column is an upper bound for the year of 2035.

Air Pollution Dispersion Modeling

The city of Shanghai was selected for air pollution exposure level forecasting and was built into the air quality modeling system. Air quality models included point, volume, area, and linear dispersion models linked with the Shanghai Environmental GIS (SEGIS). SEGIS, updated in 2000, contains all useful information related to SO_2 and NOx emissions, e.g. power plants, industrial and commercial boilers, and road way systemand it was linked to air quality models. The model applied in this study had been calibrated/verified and applied successfully in the project of Computer Support System on Shanghai SO_2 emission control (1997), and project of NOx emission inventory and pollution contribution in Shanghai (February 2000). The relative error of air quality modeling was within ±50%.

Principle and Approach for Health Effects Analysis

a. Study Hypotheses and Basic Assumption

Some study hypotheses were made in the health effects analysis as follows:

❖ Ambient air quality (levels of suspended particulate matter, sulphur dioxide and nitrogen oxide) is related to energy structure and amount of energy consumption;

❖ Mortality and morbidity increase as ambient air quality deteriorates.

❖ The dose-response relationship is assumed to be linear within the segment of the dose-response curve to which the population is exposed under normal conditions.

b. Air Quality Guidelines Used

Assessment of ambient air quality for public health purposes consists essentially of examining ambient air quality against air quality guidelines. The primary aim of the World Health Organization Guideline (WHO/AQG) is to provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants that are known or likely to be hazardous to human health and wellbeing. Therefore the WHO/AQG are used in the assessment of the impact of ambient air pollution since they are based solely upon health effects of air pollution.

c. Population Under Study

The study considered the areas of Shanghai with high population density and significant likelihood of exposure to high pollutant levels. Thus the study included all people living in the 10 central urban districts for the health analysis.

d. Health End-Points Studied

Air pollution in Shanghai was basically dominated by coal use until around 1980. Since then, with the rapid increase in the number of motor vehicles and relocation of coal-using factories from the "Inner Ring Road" to suburban areas, transformation of high-pollution industries through end-of-pipe treatment to low-pollution ones, shut-down of high polluting plants and change of sources of energy, air pollution in the urban districts gradually assumes the character of a combination of emissions from coal combustion and emission from motor vehicles, resulting in decreasing level of TSP and SO_2, and increasing level of nitrogen oxides [and VOCs].

Therefore health end-points studied in this assessment are related to pollutants emitted both from coal combustion and combustion of petroleum products, i.e., changes in mortality and morbidity from respiratory diseases, cardiovascular diseases, cerebrovascular diseases, etc., as well as total mortality and number of out-patient and emergency-room visits. Increase in clinical symptoms and decreases in lung functions are also studied. Though there were studies on the impact of air pollution on pre-term delivery and other pregnancy outcomes, the literature is too limited to make a quantitative analysis possible.

e. Methods Used for Health Effects Impact Assessment

The internationally accepted quantitative risk assessment approach (hazard identification, exposure assessment, and dose-response assessment and risk characterization) is used in this assessment. Quantitative estimates of the health effects of major air pollutants in relation to change in energy structure and consumption, and hence to air pollution levels, are performed.

This assessment is based on the 1990-1999 data in Shanghai, including ambient air pollution levels, number of population in the 10 central urban districts, as well as mortality and morbidity data. Since the most recent population census was conducted in 1990, data on age distribution of the population in Shanghai is based on the 1990 census data.

Assessment of the effect of air pollution is limited to the adverse effects of ambient air pollution, while acknowledging that almost all the people in Shanghai are exposed to some degree of indoor air pollution. Fortunately due to change of source of energy for domestic cooking, use coal briquettes has gradually phased out and now almost all the people living within the "Inner Ring Road" turn to from coal to natural gas for domestic cooking and to electricity for heating.

The percentage increase in mortality per unit increase in air pollution levels is used as the basic approach in assessing health impacts. The estimated increments are based on epidemiological data from Shanghai or other cities in China. If relevant data are not available, estimates are made by extrapolating from dose-response relationships derived from studies conducted in other countries.

Exposure-response relationships in Established Market Economy countries (EME), Former Socialist Economy countries (FSE), cities of China (Shenyang, Beijing, Benxi) are used in this study, which are listed in Annex 4.

ANALYTIC RESULTS

Energy Input from Different Scenarios

As shown in Figure 1, after energy and environment policies are implemented, the energy supply structure of Shanghai will have notable changes. Under this scenario, until 2020, coal input will be limited to 50 Mt, and the proportion of coal will be reduced from 67% in 1995 to 45%, crude oil supply will grow from 31% in 1995 to 32%, natural gas supply will reach 21%, and imported electricity 3%.

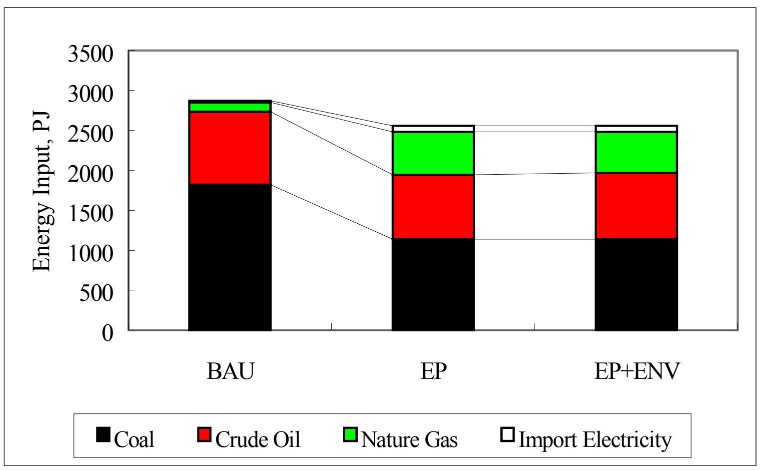

Fig. 1 Energy input by different scenarios, 2020

Shanghai's total energy input in 2020 will be reduced to 2555 PJ under the energy policy scenario, which is 89% of the BAU scenario’s and 1.92 times of that of 1995. The total energy input between EP and EP+ENV scenario is nearly the same.

Under the energy and environment policies, coal and crude oil inputs will be limited/reduced to 1137 PJ (50 Mt) and 832 PJ in 2020, which are 62% and 91% of BAU scenario. Natural gas from East China Sea and Western China, and electricity from Qinshan Nuclear Power Station and the Three Gorges Project will reach 513 PJ and 78 PJ in 2020, which are 4.4 times and 4.3 times the BAU scenario, respectively.

With the limitation of coal use in the city, residential energy use for cooking, and small and medium size coal boilers will shift their energy source from coal to natural gas. And coal will be mainly used for power generation, coke and coal gas production.

Air Pollution Emission Reduction and Co-benefit

Markal results indicate that the total SO_2 emission for the city in 2020 will be reduced to 375 kt, which is 71% of that in 1995 under energy and environment policies, while the total NOx emission in 2020 will grow slowly increasing to 421 kt, which is 120% of that in 1995.

Compared with the BAU scenario, Shanghai will have a SO_2 reduction of 65% in 2020 city-wide. In the meantime, NOx emission reduction in 2020 will be reduced to 48% of the BAU scenario (see Figure 2 and Figure 3). Air pollution emissions by scenario over time are graphed in Annex 1 and Annex 2.

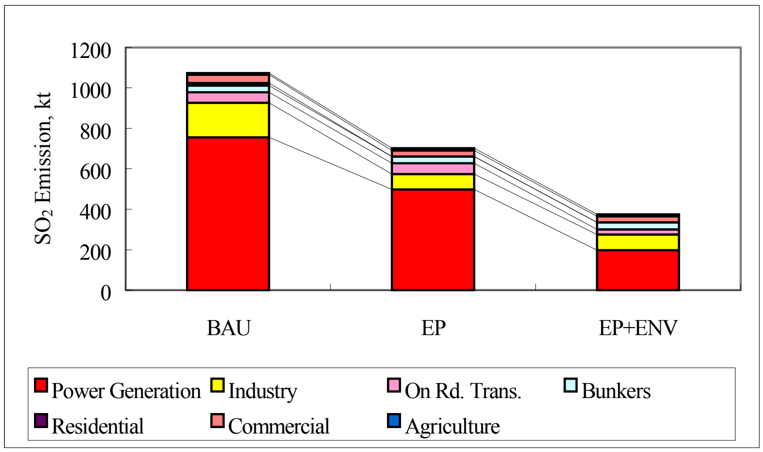

Fig. 2 SO_2 emissions by different scenarios, 2020

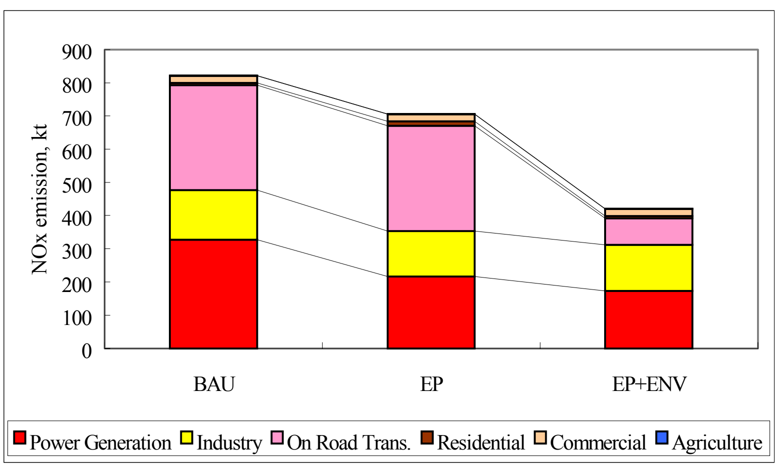

Fig. 3 NOx emissions by different scenarios, 2020

Energy and environment policies (mainly energy policies) will also have a positive effect on CO_2 reduction. Compared with the BAU scenario, total CO_2 emission will be reduced from 238 Mt in 2020 in the BAU scenario to 190 Mt in the EP+ENV scenario, which is a 20% CO_2 reduction co-benefit. CO_2 emissions by scenario over time are graphed in Annex 3.

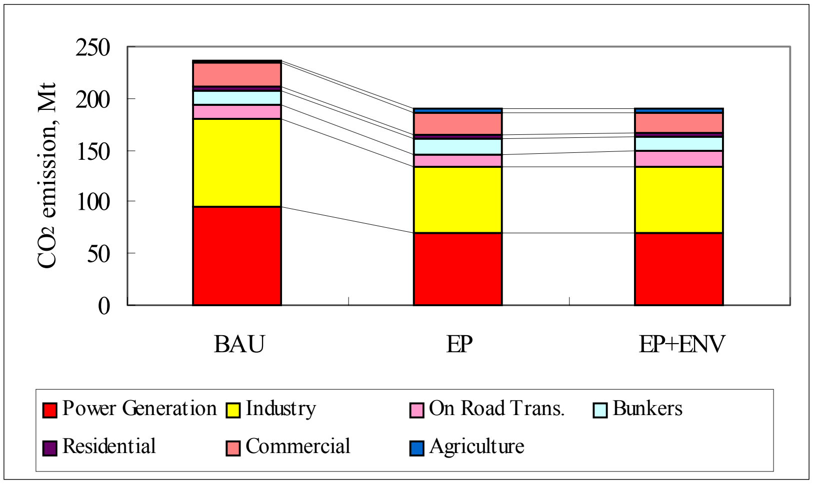

Fig. 4 CO_2 emissions by different scenarios, 2020

Energy Technology Improvement Supporting for Emission Reductions

Figure 5 to Figure 7, produced by Markal, show the changes in the capacity of power plant in Shanghai, which is the best illustration of energy technology improvement for air pollution and CO_2 emission reductions. It can be seen that the capacity of coal steam cycle with lower energy efficiency will be reduced, and coal USC and CHP with higher energy efficiency will be increased as a substitute.

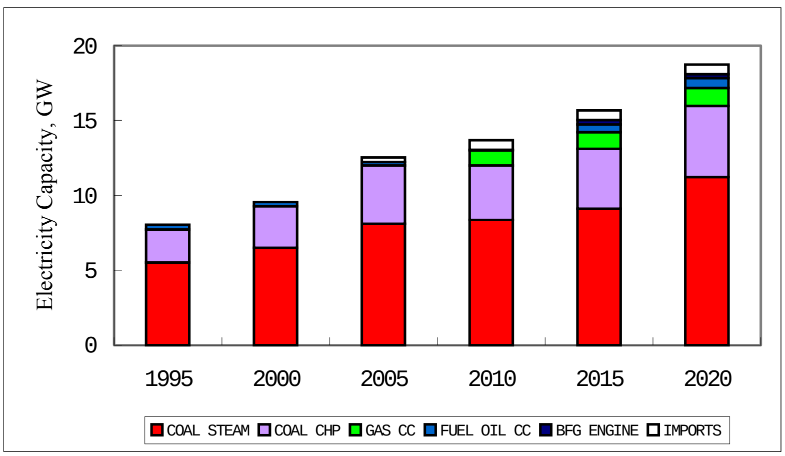

Figure 5 Capacity of different type of power plants in the BAU scenario, 2000~2020

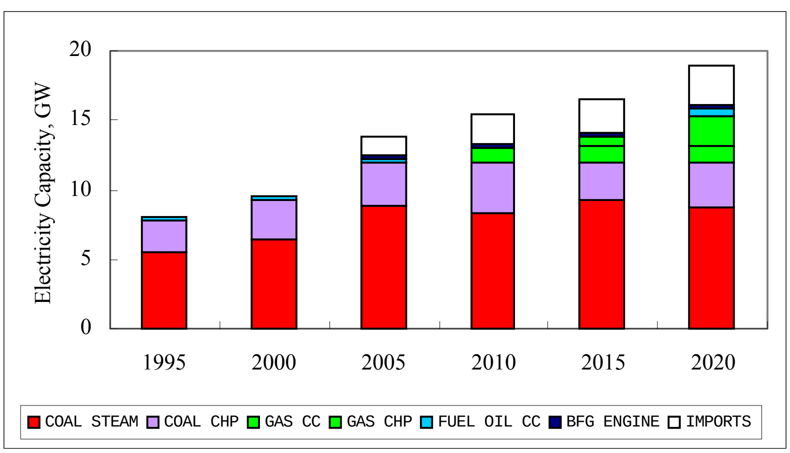

Figure 6 Capacity of different type of power plants in the EP scenario, 2000~2020

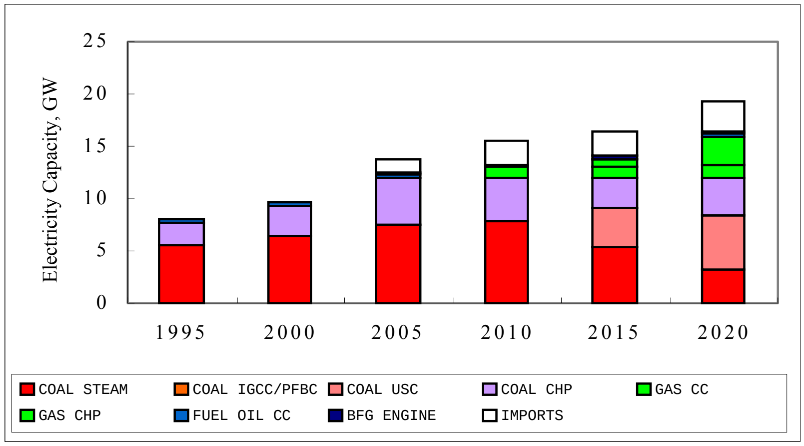

Figure 7 Capacity of different type of power plants in the EP+ENV scenario, 2000~2020

Air Pollution Exposure Levels

For ground level of air pollution exposure forecasting, point, area, volume and linear dispersion models were selected automatically depending on emission characterization by the air quality simulation module which is linked with Shanghai Environmental GIS. Figure 8 and Figure 9 show the SO_2 and NOx exposure levels in annual concentration on the scale of 1×1 km^2 under BAU and EP+ENV scenarios in 2020. It is clearly indicated that, if there were no energy and environment policy to be implemented in future, Shanghai air quality will be heavily polluted by SO_2. 41% of the total city area will have SO_2 exposure levels in 2020 exceeding Class II (0.06 mg/m^3) of the National Air Quality Standards (GB-3095-1996), see Table 5.

Table 5 SO_2 Exposure Levels and Areas, 2020unit: km^2

Scenario	≤ Class I ≤ 0.02 mg/m^3	Class I-II 0.02-0.06 mg/m^3	Class II-III 0.06-0.10 mg/m^3	> Class III > 0.10 mg/m^3
EP	202	3572	1669	988
EP+ENV	2344	3661	340	86

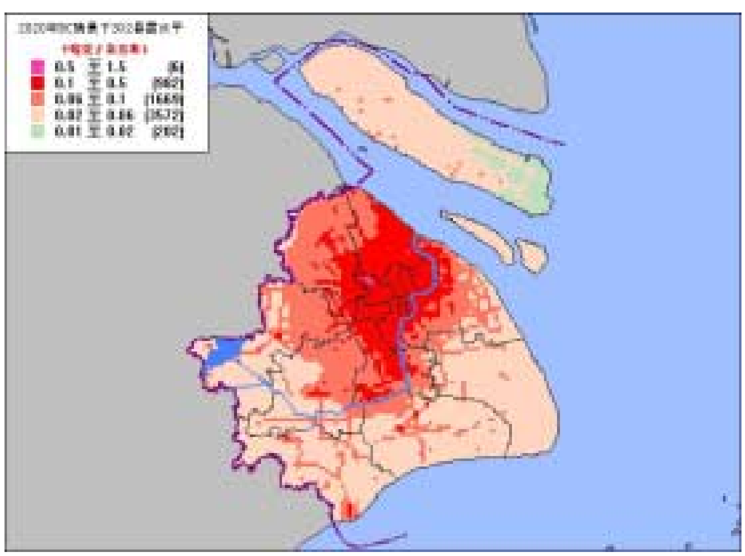

Figure 8(a) SO_2 exposure level under BAU scenario in 2020

As shown in Figure 8(b), if energy and environment policies are implemented, air quality in terms of SO_2 exposure levels would be improved. The area of exposure level greater than Class III would be reduced to 86 km^2, while area of exposure level better than Class I would increased from 202 km^2 to 2344 km^2, (see Table 5).

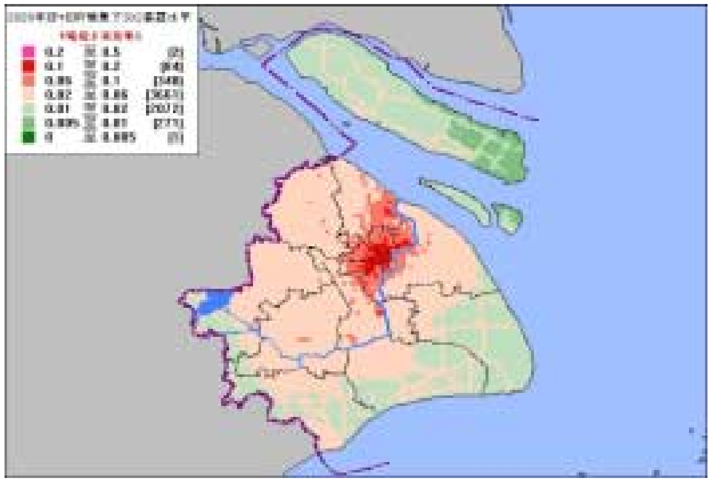

Figure 8(b) SO_2 exposure level under EP+ENV scenarios in 2020

Figure 9(a) shows the NOx exposure levels under the BAU scenario. It is indicated that, if there were no with no energy and environment policy to be implemented in 2020, the air quality in Shanghai will be very much heavily polluted by NOx. 96% of the total city area would be exposed to higher NOx pollution levels exceeding Class III (0.10 mg/m^3) of the National Air Quality Standards (GB-3095-1996), and areas with NOx quality better than Class II will be down to zero (see Table 6). The most polluted area will be located in the city center and suburban areas with higher population densities. NOx pollution is mostly caused by emissions from vehicle and small size boilers.

Table 6 NOx Exposure Levels and Areas, 2020 unit: km^2

Scenario	≤ Class II ≤ 0.05 mg/m^3	Class II-III 0.05-0.10 mg/m^3	> Class III > 0.10 mg/m^3
EP	0	275	6156
EP+ENV	5534	703	194

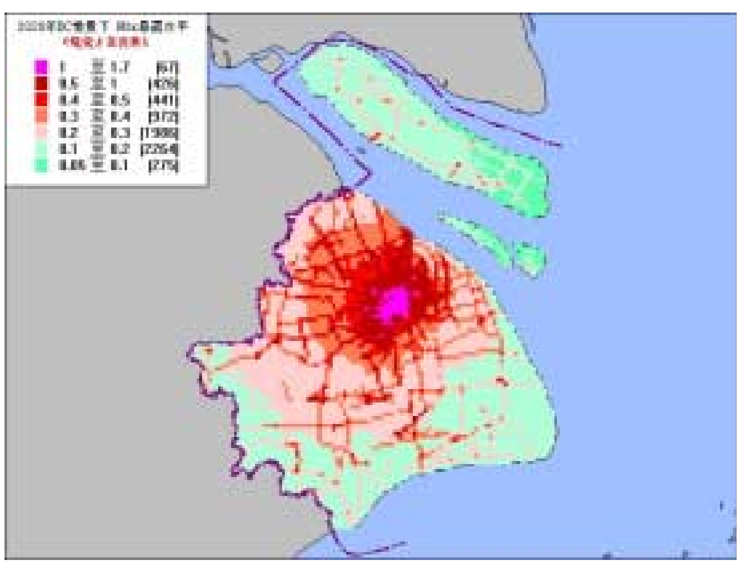

Figure 9(a) NOx exposure level under BAU scenario in 2020

As shown in Figure 9(b), if energy and environment policies were implemented, air quality related to NOx pollution would be improved greatly. The area of exposure level greater than Class III would be reduced from 6156 km^2 to 194 km^2, while the area of exposure level better than Class II would reach to 5534 km^2 (see Table 6).

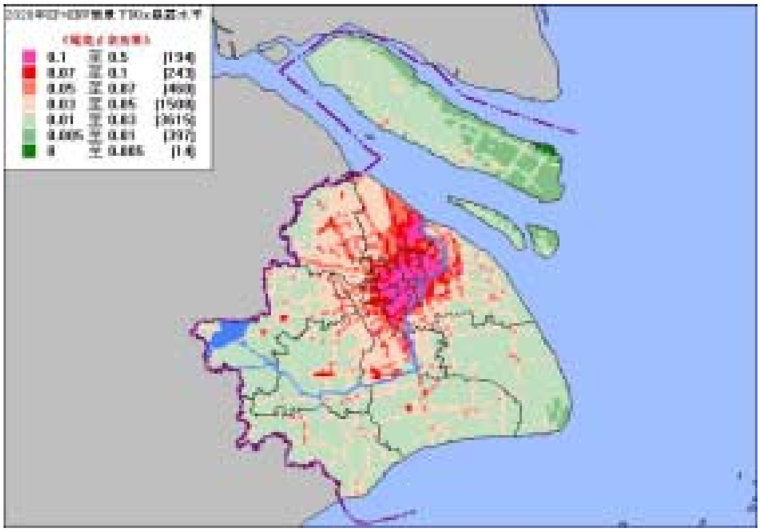

Figure 9(b) NOx exposure level under EP+ENV scenarios in 2020

Health Effects

Health effects associated with the projected changes in air pollution emissions for this study have not yet been calculated. This health effects analysis will be completed over the next several months. Information is presented in this section on current and historic health effects (from 1990-1999) that will provide a baseline for this analysis.

The total number of avoidable deaths due to TSP exposure in 1999 was estimated at 450-2000, with 80-230 avoidable deaths were from chronic obstructive pulmonary diseases, 60-300 from cardiovascular diseases, 10-20 from pneumonia and only 1 avoidable death from pulmonary heart disease. Since the annual mean level of SO_2 was below the WHO/AQG guideline, no avoidable deaths from exposure to SO_2 were expected.

The number of avoidable chronic bronchitis cases in urban districts of Shanghai due to TSP exposure in 1999 was estimated at 30,800, among which 15,200 occurred in the people 45-60 years of age. The number of avoidable respiratory disease cases from NO_2 exposure was estimated at 94,900. Due to rapid increase in the number of motor vehicles and related increase in NOx level in recent years, the number of avoidable respiratory disease cases was estimated to have increased from 54,200 in 1990 to 98900 in 1998, a 83% increase. The number of avoidable respiratory disease cases decreased to 94,900 in 1999.

It was difficult to make a quantitative estimate of the impact of ambient air pollution on respiratory disease symptoms and lung function. In 1990, the increase in respiratory symptoms such as cough and phlegm were estimated at 48% and 55% respectively from exposure to TSP, 23% and 53% for cough and shortness of breath due to exposure to SO_2. The excess due to TSP exposure was reduced to around 10-11% for cough and phlegm respectively in 1999.

As for changes in lung function, it was estimated that there would be a reduction of 230 ml in Forced Respiratory Flow (FVC) and a reduction of 63 ml in First Second Forced Respiratory Volume ($FEV_{1.0}$) from exposure to TSP in 1999. The reduction in FVC and $FEV_{1.0}$ was estimated at 89 ml and 88 ml respectively from exposure to NOx. The reduction in lung function from exposure to TSP and SO_2 was very significant in 1990, while the effect of NOx was pronounced in 1999. Though no disease can be directly linked to such change as yet, their potential risk and significance should be monitored at intervals so that appropriate measures can be taken when there is a need to do so.

Though other changes such as pre-term delivery and low birth weight associated with ambient air pollution were reported, the results have not yet been duplicated elsewhere and the reduction of a few hours or grams does not seem to warrant a more detailed analysis at this stage.

Summary and Conclusions

(1) Implementation of energy and environmental policies will effectively improve the ambient air quality in Shanghai and reduce the pollutant exposure level and CO_2 emission.

(2) Under the energy policies scenario, coal consumption will decrease from 67% in 1995 to 45% in 2020; raw oil will increase from 31% in 1995 to 32%; natural gas will account for 21%; and 3% of electricity will be imported from other provinces.

(3) Under the energy policies scenario, CO_2 emission in Shanghai in 2020 will decrease from 238 Mt to 189 Mt; SO_2 emission will decline from 1075Mt to 702 Mt; NOx will decrease from 822 kt to 706 kt. Emission reduction from CO_2, SO_2 and NOx will be 21%, 35% and 14% respectively.

(4) Under the EP+SO_2 emission control scenario, all the coal-burning domestic, commercial and medium-or-small sized boilers will be supplied with natural gas. SO_2 emissions from power plant will decrease from 497 kt under EP scenario to 170 kt, a 66% reduction. The total emission load of SO_2 will be controlled below 400 kt.

(5) Under EP+SO_2+NOx emission control scenario assumptions, effective control over vehicle exhaust is achieved, capacity of coal-combustion steam turbine power plants is limited to below 3.28 GW, coal CHP increases to 3.54 GW, coal USC increases to 5.18 GW, and natural gas combined cycle and gas CHP cycle increases to 3.98 GW. Under these assumptions, NOx emissions can meet the state requirement of total load control.

(6) Compared with BC scenario, with the effective energy and environmental policies (EP+ ENV), exposure level of SO_2 of Shanghai in 2020 will be same as that of 1998. If NOx pollution is effectively controlled, exposure level of NOx will be greatly improved.

Outcome of Final Project Meeting and Next Steps

The Shanghai project report and the work to date provides a good foundation for analysis of integrated strategies for Shanghai and their relationships to national energy and environmental policies. The workshop participants recognized the significant accomplishments of the Shanghai team in producing the draft report with limited time and resources. Several key areas were identified for further work. A few of these areas will require additional resources and technical assistance. These areas include:

(1) Public health effects analysis: Further work is needed on extending the health effect analysis to relate this analysis to future energy options and scenarios.

(2) Public health effects analysis: Further work to strengthen and improve the analysis methodology followed in estimating health effects including .averaging times for pollutant concentrations, dose/response functions, accounting for confounding factors such as weather, adoption of dose/response coefficients from other cities in China, the magnitude

of the coefficients used, and the linearity of the dose/response functions used should be explored further.

(3) Integrated Scenarios: Further development of integrated environmental scenarios including economic, energy, technology scenarios with additional attention to energy efficiency and fuel substitution potentials with the MARKAL model.

(4) Improved understanding and scope of emission inventory development and air quality modeling including new pollutants such as TSP, PM10 and PM2.5 which are considered major contributors to adverse health effects in Shanghai. Additionally, interest was also expressed in attempting to model concentrations of secondary particulates, given that work to model sulfur and nitrogen is already completed.

(5) Economic valuation of health effects: Economic valuation has not yet been attempted in the Shanghai project. It was agreed that valuation of health effects would be a valuable task for future activities.

ABBREVIATIONS

CCICED	China Council for International Cooperation on Environment and Development
USEPA	United States Environmental Protection Agency
SEPB	Shanghai Environmental Protection Bureau
WRI	World Resources Institute
SAES	Shanghai Academy of Environmental Academy
SMU	Shanghai Medical University
SEGIS	Shanghai Environmental Geographic Information System
BAU	Business As Usual
EP	Energy Option scenario
ENV	Environment policy scenario
EP+ENV	Energy Option scenario + Environment policy scenario
TGP	The Three Gorges project
ECS	East China Sea
LNG	Liquefied Nature Gas
COPD	Chronic obstructive pulmonary disease
CVD	Cardiovascular diseases
CEVD	Cerebrovascular diseases
ARI	Refers to pneumonia
RD	Respiratory diseases
PHD	Pulmonary heart disease, cor pulmonale
OPVs	Out-patient visits
ERVs	Emergency-room visits
I.M.	Internal medicine
Paed.	Pediatrics
FVC	Forced respiratory flow
FEV	Forced expiratory volume

ANNEXES FOR CHINA STUDY

ANNEX 1
SHANGHAI ENERGY INPUT BY SCENARIO OVER TIME

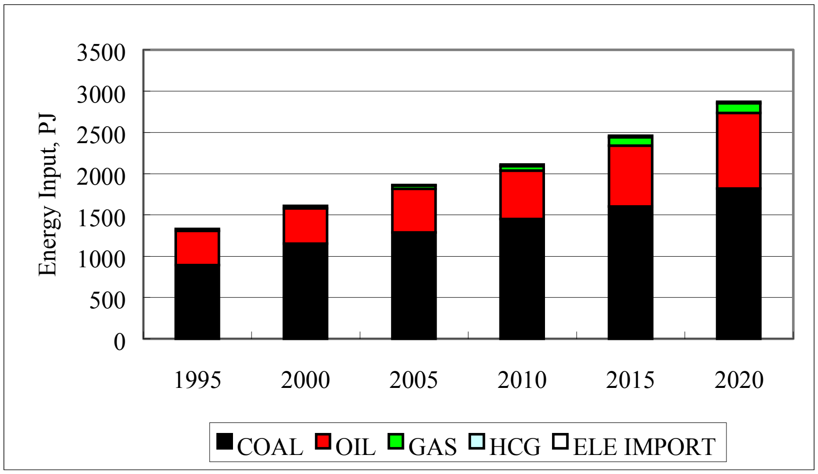

Figure 1 Shanghai Energy Input under BAU Scenario
(source: Figure 7-1 in energy part in the report)

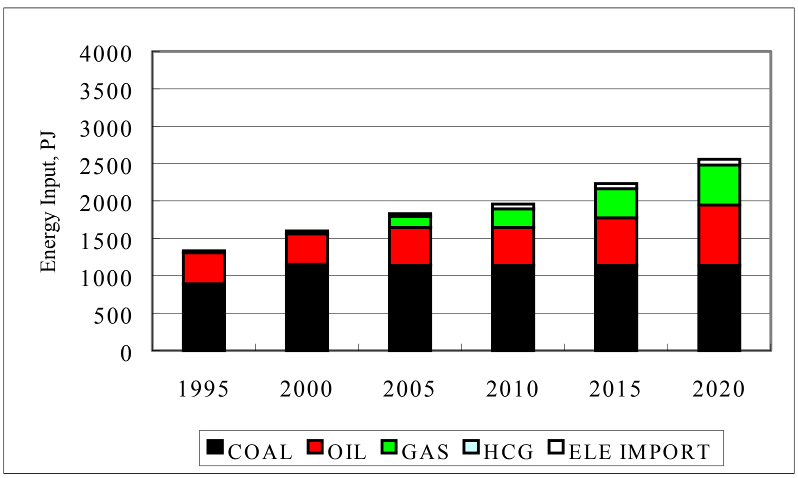

Figure 2 Shanghai Energy Input under EP Scenario
(source: Figure 7-2 energy part in the report)

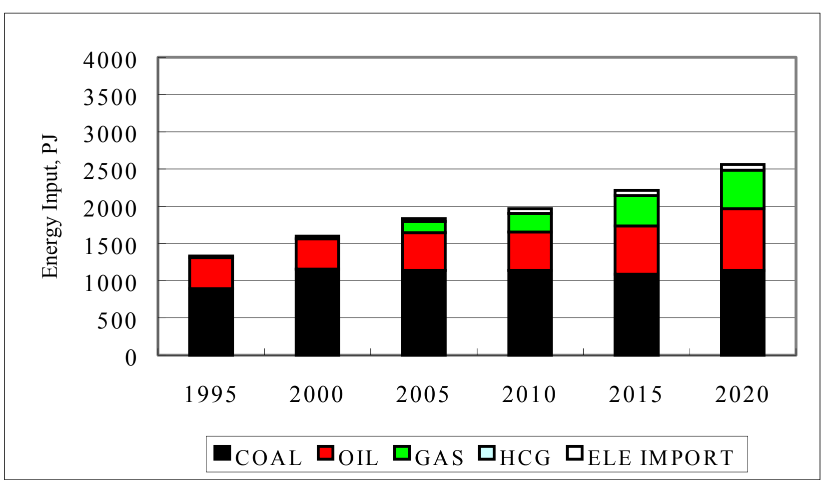

Figure 3 Shanghai Energy Input under EP+ENV Scenario
(source: Figure 8-3 energy part in the report)

ANNEX 2

AIR POLLUTION EMISSIONS BY SCENARIO OVER TIME

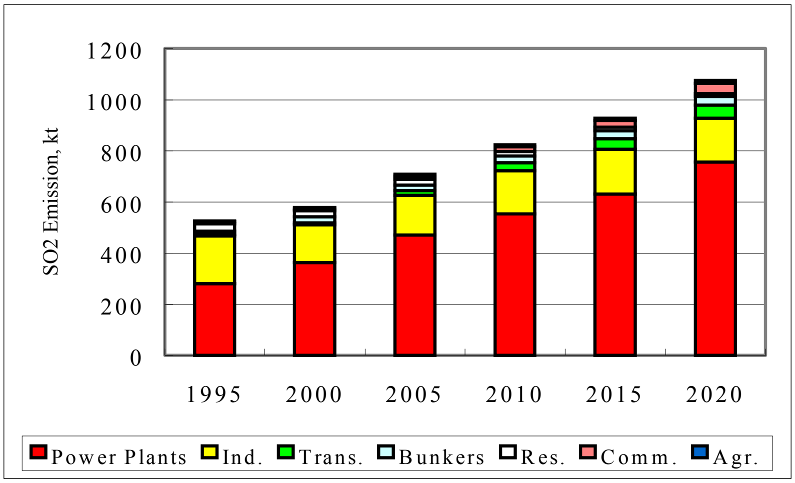

Figure 4 SO_2 emissions under BAU Scenario
(source: Figure 7-13 in energy part in the report)

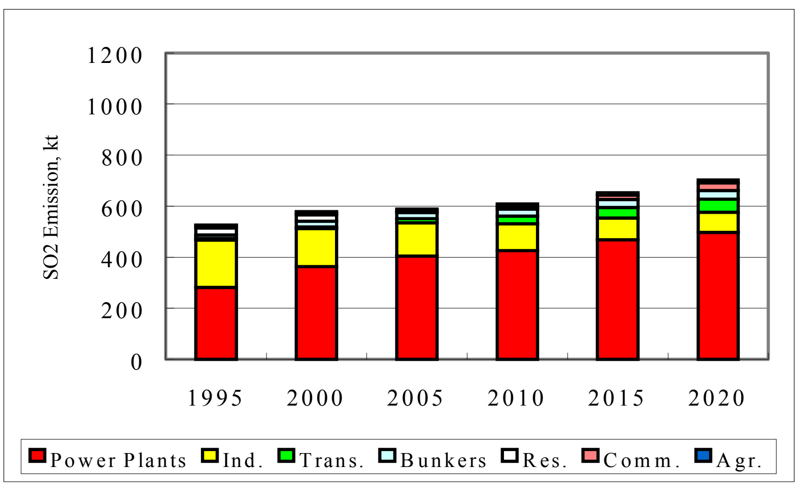

Figure 5 SO_2 emissions under EP Scenario
(source: Figure 7-14 in energy part in the report)

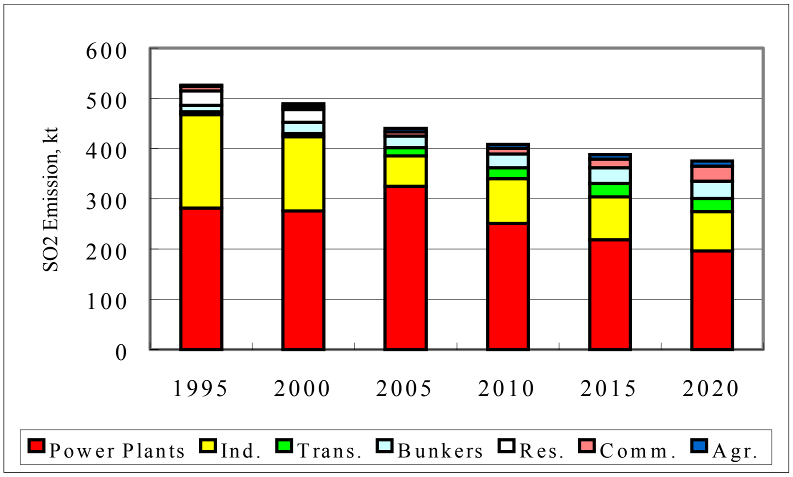

Figure 6 SO$_2$ emissions under EP+ENV Scenario
(source: Figure 8-21 in energy part in the report)

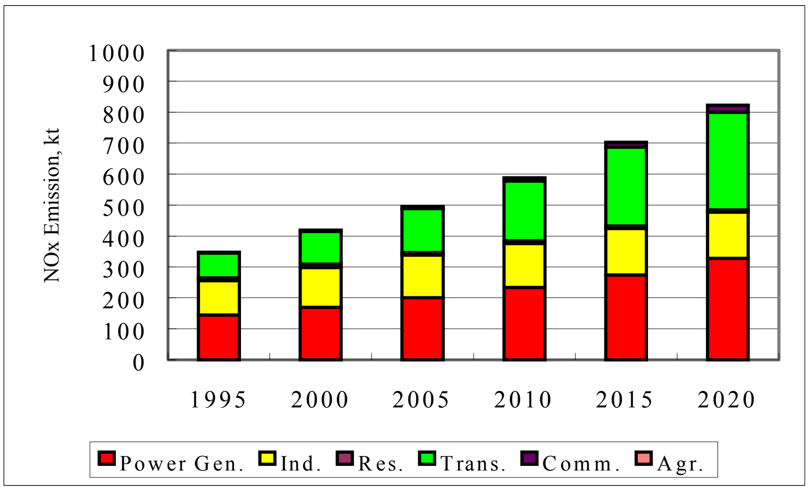

Figure 7 NOx emissions under BAU Scenario
(source: Figure 7-15 in energy part in the report)

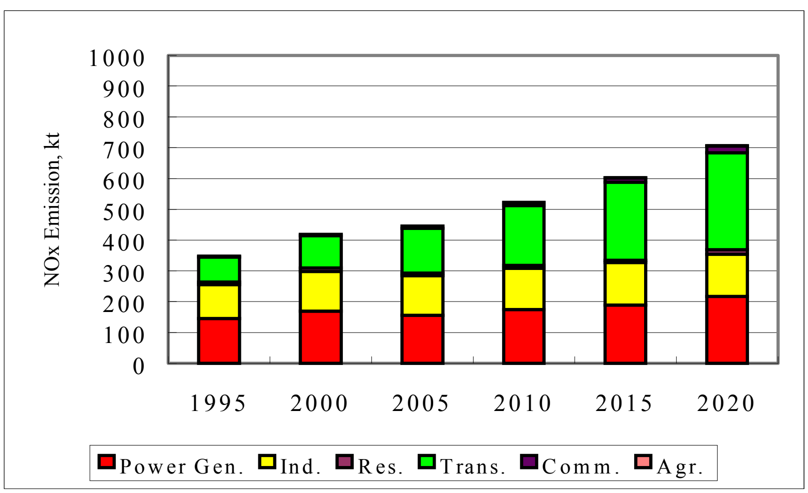

Figure 8 NOx emissions under EP Scenario
(source: Figure 7-16 in energy part in the report)

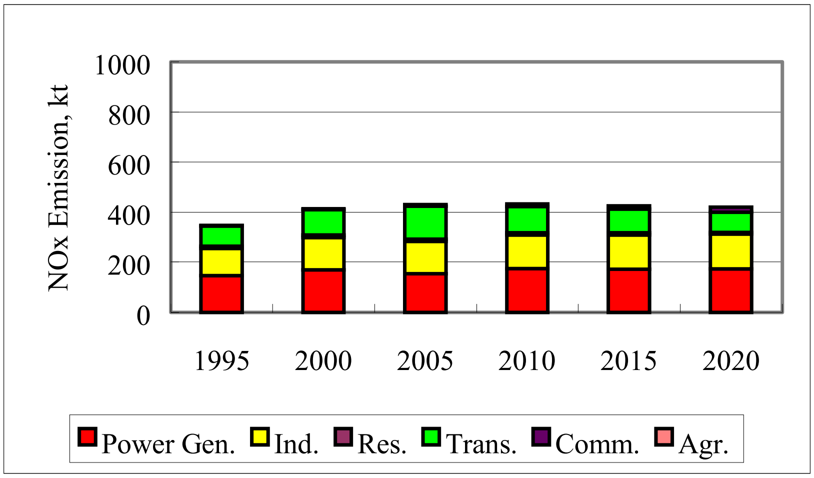

Figure 9 NOx emissions under EP+ENV Scenario
(source: Figure 8-24 in energy part in the report)

ANNEX 3

CO_2 EMISSIONS BY SCENARIO OVER TIME

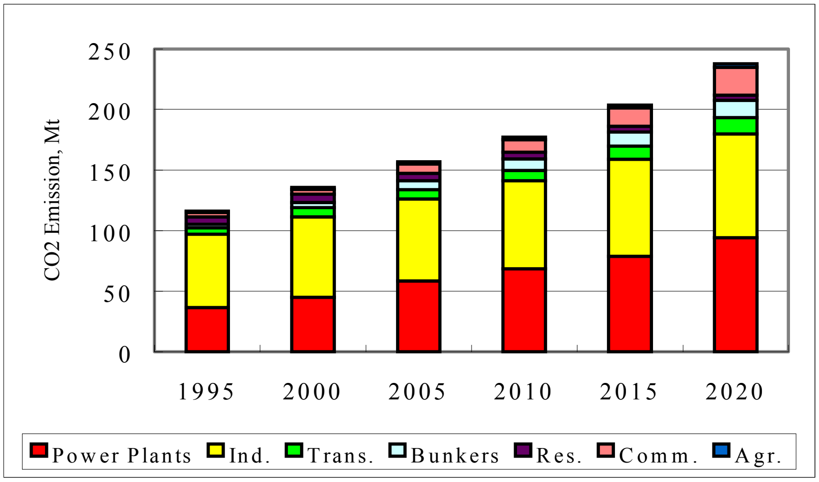

Figure 10 CO_2 emissions under BAU Scenario
(source: Figure 7-11 in energy part in the report)

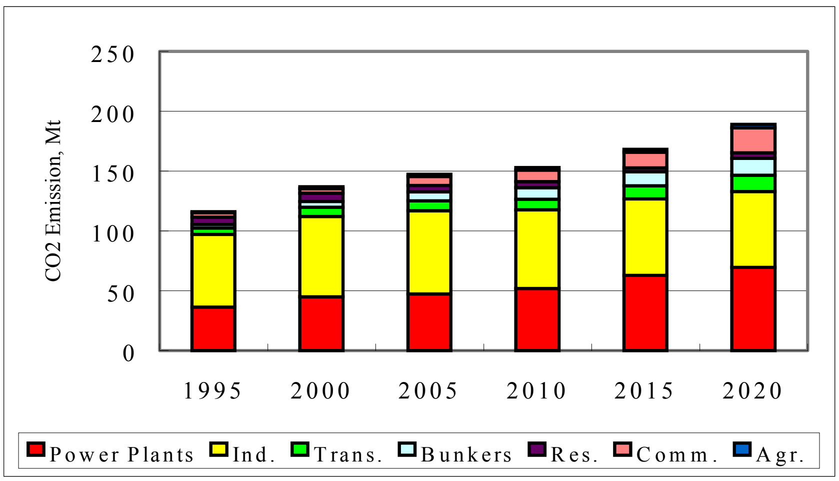

Figure 11 CO_2 emissions under EP Scenario
(source: Figure 7-12 in energy part in the report)

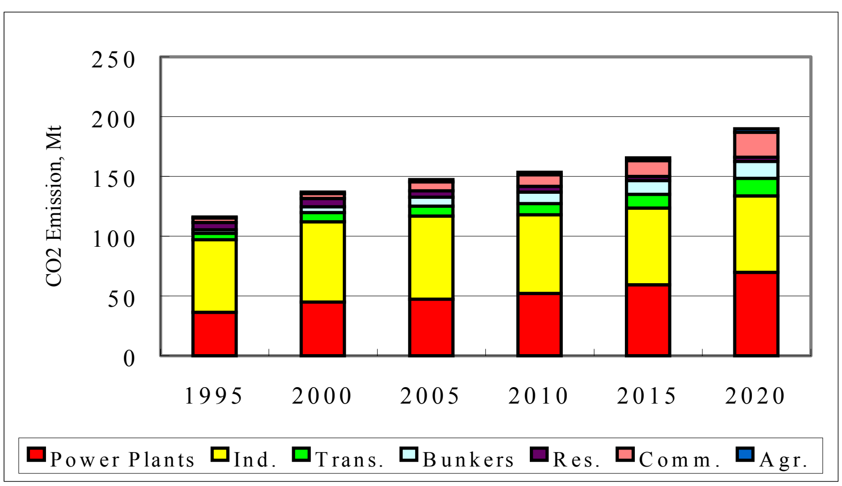

Figure 12 CO_2 emissions under EP+ENV Scenario
(source: Figure 8-18 in energy part in the report)

ANNEX 4

INCREASE IN MORTALITY AND MORBIDITY PER UNIT INCREASE IN POLLUTANT EXPOSURE LEVEL

a. Change in Mortality

Table 1(a) Percentage Increase in Total Mortality and some of the Cause-Specific Mortality in Urban Districts of Shanghai from TSP Exposure* unit: %

Mortality	1990	1998	1999
Total	4.8-21.6	1.9-8.6	1.0-4.3
COPD	7.2-21.6	2.9-8.6	1.4-4.3
CVD	4.8-24.0	1.9-9.5	1.0-4.8
CEVD	19.2	7.6	3.8
ARI (Pneumonia)	26.4-38.4	10.5-15.2	5.3-7.7
Cor pulmonale	45.6	10.1	9.1

* Source: in Table 29 of health part in the report.

Table 1(b) Estimates of the Impact of TSP Exposure on Total Mortality and some of the Cause-Specific Mortality in Terms of Number of Avoidable Deaths in Urban Districts of Shanghai*

Mortality	1990		1998		1999	
	Increase per 100,000	No. of avoidable deaths	Increase per 100,000	No. of avoidable deaths	Increase per 100,000	No. of avoidable deaths
Total	32.78-127.15	2300-9000	15.35-64.85	1000-4100	7.25-31.59	450-2000
COPD	6.47-17.12	450-1200	2.79-7.93	200-500	1.25-3.64	80-230
CVD	3.31-13.98	230-1000	1.67-7.86	100-500	0.94-4.54	60-300
CEVD	23.26	1600	12.82	800	6.45	400
ARI (Pneumonia)	0.83-1.11	60-80	0.49-0.69	30-40	0.21-0.30	10-20
Cor pulmonale	0.15	10	0.04	2	0.02	1

* Source: in Table 30 to Table 32 of health part in the report.

Table 2(a) Percentage Increase in Total Mortality and some of the Cause-Specific Mortality in Urban Districts of Shanghai from SO_2 Exposure* unit: %

Mortality	1990	1998
Total	0.9-5.0	0.1-0.3
COPD	3.1-13.1	0.2-0.9
CVD	0.9-5.0	0.1-0.3
CEVD	0.9	0.06
Cor pulmonale	8.6	0.6

* Source: in Table 33 of health part in the report.

Table 2(b) Estimates of the Impact of SO_2 Exposure on Total Mortality and some of the Cause-Specific Mortality in Terms of Number of Avoidable Deaths in Urban Districts of Shanghai*

Mortality	1990		1998	
	Increase per 100,000	No. of avoidable deaths	Increase per 100,000	No. of avoidable deaths
Total	6.39-33.76	450-2400	0.49-2.71	30-170
COPD	2.94-11.12	200-800	0.21-0.87	10-60
CVD	0.64-3.41	50-240	0.05-0.30	3-20
CEVD	11.93	840	0.11	7
Cor pulmonale	0.04	3	0.0013	< 1

* Source: in Table 34 to Table 35 of health part in the report.

b. Change in Morbidity

Table 3 Estimates of Percentage Increase in Morbidity from TSP, SO_2 and NO_2 Exposure in Urban Districts of Shanghai* unit: %

	Morbidity	1990	1998	1999
TSP	Chronic bronchitis	69.6	27.6	17.7
	COPD	69.6	27.6	
SO_2	COPD	10.8-16.2	0.7-1.1	
	ERVs	3.1-10.8	0.2-0.7	
	COPD ERVs	16.2	1.1	
	Chronic bronchitis	24.0	1.6	
	OPVs – I.M.	6.3	0.42	
	OPVs – Paed.	5.4	0.36	
NO_2	Respiratory diseases	8.3	18.6	17.7

* Source: in Table 36 of health part in the report.

Table 4 Estimates of the Impact of TSP exposure on Morbidity in Terms of Number of Avoidable Cases in Urban Districts of Shanghai*

Mortality	1990		1998		1999	
	Increase in prevalence %	No. of avoidable cases	Increase in prevalence %	No. of avoidable cases	Increase in prevalence %	No. of avoidable cases
COPD	2.46	173,500	1.30	81,700	0.73	46,300
Chronic bronchitis	1.64	115,600	0.86	54,500	0.49	30,800
Chronic bronchitis among those 45-60 years of age	5.34	57,000	2.81	26,900	1.59	15,200

* Source: in Table 37 to Table 39 of health part in the report.

Table 5 Estimates of the Impact of SO_2 Exposure on Morbidity in Terms of Number of Increase in Prevalence and Number of Avoidable Cases in Urban Districts of Shanghai*

Mortality, OPVs or ERVs	1990		1998	
	Increase in prevalence, OPVs or ERVs	No. of avoidable cases, OPVs or ERVs	Increase in prevalence, OPVs or ERVs	No. of avoidable cases, OPVs or ERVs
COPD	0.58-0.84%	41,200-59,000[1)]	0.043-0.064%	2,700-4,000
COPD among those 45-60 years of age	1.27-1.81%	13,500-19,400	0.093-0.139%	900-1,300
OPVs – COPD	0.0014-0.002 times/person/year	9,900-14,100	0.0001-0.00015 times/person/year	600-1,000
Chronic bronchitis	0.77%	54,600[2)]	0.063%	4,000
OPVs – Internal Medicine	0.07 times/person/year	515,800	0.005 times/person/year	32,200
OPVs – Paediatrics	0.13 times/child/year	157,500	0.0065 times/person/year	7,000
EMVs – all	0.015-0.048 times/person/year	101,900-334,600	0.001 times/person/year	6,600-23,200
EMVs – COPD	0.0012 times/person/year	1,400		100

* Source: in Table 40 to Table 41 of health part in the report.

1) This estimate was based on a study with a 6-9% increase in COPD OPVs per unit increase of 25 mcg/m^3 of SO_2.
2) This estimate was based on another study with a 32% increase in COPD prevalence per unit increase of 60 mcg/m^3 of SO_2.

Table 6 Estimates of the Impact of NOx Exposure on Respiratory Disease Morbidity in Urban Districts of Shanghai*

	1990	1998	1999
Increase in prevalence	0.77 %	1.57 %	1.50 %
No. of avoidable respiratory disease cases	54200	98,900	94,900

* Source: in Table 42 of health part in the report.

c. Other Changes

Table 8 Estimates of Percentage Increase in Respiratory Symptoms from Exposure to Ambient Air Pollution in Urban Districts of Shanghai* unit: %

Pollutant	Year	Cough	Phlegm	Shortness of breath
TSP	1990	48.0	55.2	
	1998	19.0	21.9	
	1999	9.6	11.0	
SO_2	1990	23.3		53.3
	1998	1.6		3.6

* Source: in Table 43 of health part in the report.

Table 9 Estimates of the Impact of Ambient Air Pollution on in Lung Function in Urban Districts of Shanghai (decrement in ml) *

Pollutant	Year	FVC	$FEV_{1.0}$	MMEF
TSP	1990	1,149	315	
	1998	455	125	
	1999	230	63	
SO_2	1990	25-75	16-53	24
	1998	2-4	1-4	2
	1999	--	--	--
NOx	1990	38	37	
	1998	93	92	
	1999	89	88	

* Source: in Table 44 of health part in the report.